PROCEEDINGS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

The Boring of the Simplon Tunnel, and the Distribution of Temperature that was Encountered

Francis Fox

Proc. R. Soc. Lond. A 1905 **76**, 29-33
doi: 10.1098/rspa.1905.0002

References
Article cited in:
http://rspa.royalsocietypublishing.org/content/76/507/29.citation#related-urls

Email alerting service
Receive free email alerts when new articles cite this article - sign up in the box at the top right-hand corner of the article or click **here**

To subscribe to *Proc. R. Soc. Lond. A* go to: **http://rspa.royalsocietypublishing.org/subscriptions**

This journal is © 1905 The Royal Society

HUGHES MEDAL.

The Hughes Medal is awarded to Sir Joseph Wilson Swan, F.R.S., for his invention of the incandescent electric lamp, and his other inventions and improvements in the practical applications of electricity. Not as directly included in the award, should be mentioned his inventions in dry-plate photography, which have so much increased our powers of experimental investigation.

The Boring of the Simplon Tunnel, and the Distribution of Temperature that was encountered.

By FRANCIS FOX, M.Inst.C.E.

(Communicated by C. V. Boys, F.R.S. Received January 6,—
Read January 26, 1905.)

The construction of this great tunnel under the Swiss Alps, between Brigue in Switzerland in the valley of the Rhone, and Iselle in that of the Diveria in Italy, a distance of 19,730 metres, has been carried on upon such highly scientific lines, and has revealed such extraordinary results, that it has been thought desirable to submit them in the form of a communication to the Royal Society. They are likely to prove of considerable value and importance as regards the thermal condition of the region underlying that portion of the surface of the earth.

It is not necessary here to refer to the splendid organisation of the enterprise, nor to the humane arrangements for the welfare of the men ; but the rapidity with which the drilling has been effected, and the advance-headings driven forward, as also the excellent ventilation provided, have enabled much more trustworthy results to be obtained than would otherwise have been the case.

The Brandt hydraulic drill, by which a daily advance of 5·48 metres (18 feet) for months together, has been attained, has been described elsewhere; but the fact of its rapid advance enables the temperature of the rocks to be recorded before the lapse of a considerable time during which the rocks would be cooling. On the other hand, the very excellent system

The Royal Society is collaborating with JSTOR to digitize, preserve, and extend access to
Proceedings of the Royal Society of London. Series A, Containing Papers of a Mathematical and Physical Character. www.jstor.org

of ventilation, which has been provided, passes an enormous volume of fresh air along the galleries, thus tending to produce a lowering effect in temperature.

During the trimestral period of July, August, and September, 1904, the average volume of air introduced into the tunnel daily was as follows:—

From the Brigue portal	2,934,140 cub. metres
From the Iselle	2,361,310 „
Or a total of	5,295,450 „

equivalent to 33·9 cub. metres per second at Brigue and 27·3 cub. metres per second at Iselle. During this period the average temperature of the external air was 17°·5 C., that of the travelling air in the advanced headings being from 27°·1 to 29°·7 C.

As the advanced gallery was proceeded with, a series of holes were bored into the side of the tunnel, in a horizontal position, to a depth of 1·5 metres, at a distance apart of 1000 metres. Into each hole was introduced a permanent thermometer, from which observations were made and results recorded. It is not, of course, possible to place the thermometer in advance of the excavation, as it would be broken by the next "shot" in the blasting operations. It is, however, placed in position in the side wall as soon after the boring machine has gone forward as is possible. The effect of this, no doubt, is that a slight cooling of the rock occurs before the observation can be made, but this factor of error has been as far as possible allowed for in the diagram.

On the accompanying profile (fig. 1), which is drawn to natural scale, the squares being 1000 metres horizontal and vertical, is shown the position of the tunnel, with the height of the mountains above it throughout, and on the lower diagram are given the results of temperature observations, so that at a glance the heat curve may be compared with the corresponding mountain surface.

It will be observed that the maximum height of the Alps above the tunnel is 2135 metres (7005 feet), which is far greater than any depth previously attained; the maximum temperature of the rocks is 54°·5 C.

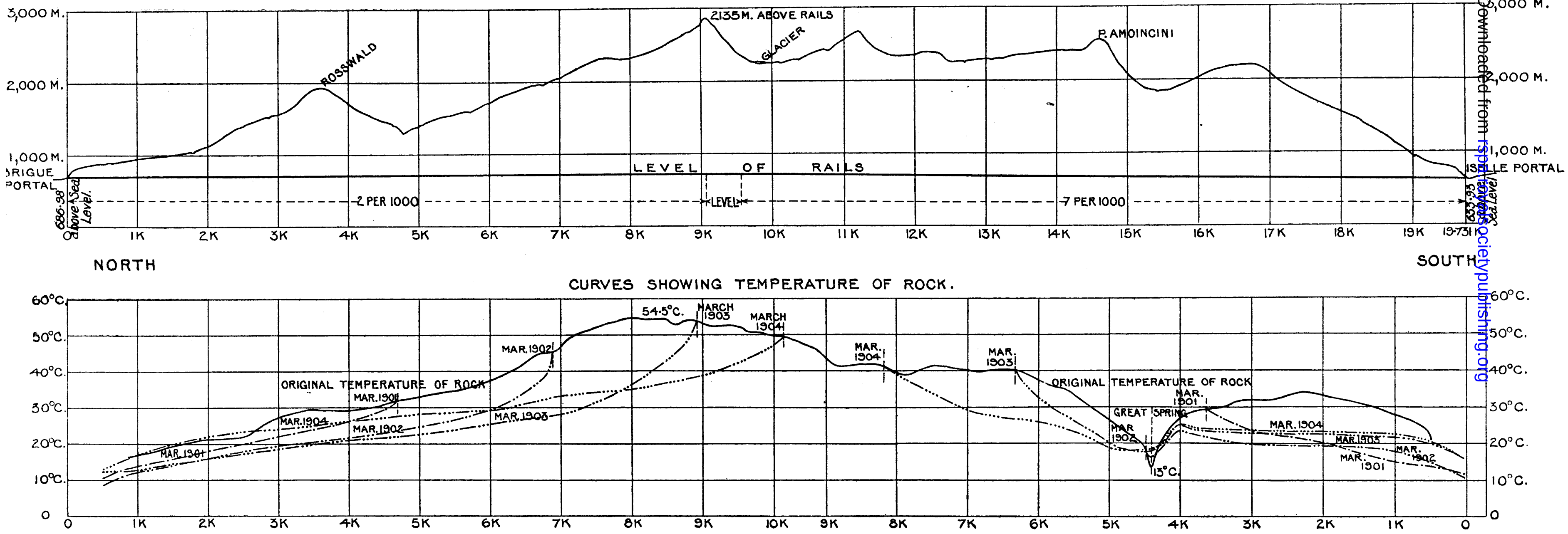
In order to show the rapid cooling of the rocks, so soon as perforation has taken place, I have selected four points on both sides, dated March, 1901, 1902, 1903, 1904; the explanation of one will suffice for the remaining three.

March, 1901 Up to that date observations had been taken from the entrance at Brigue to a distance of 4693 metres, and these are represented

Fig 1.

SIMPLON TUNNEL

LONGITUDINAL SECTION THROUGH THE ALPS.



CURVES SHOWING TEMPERATURE OF ROCK.

PROCEEDINGS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

by the thick top line on the chart. But at that actual date, the readings between that point and the portal had been lowered by cooling, as represented by the "one dot and dash" line.

Similarly in March, 1902, when the distance of 6884 metres had been reached, the readings are indicated by a "two dot and dash" line.

In March, 1903, at a distance of 8930 metres, they are given by a "three dot and dash" line; and in March, 1904, at 10,140 metres, by a "four dot and dash" line.

At the southern or Iselle side of the Alps, it will be noticed that the temperature follows approximately the increasing altitude of the mountains, until a point is reached at about 2200 metres. From that point forward as the tunnel advanced the heat began to fall off, indicating some probable change; at about 4000 metres it fell rapidly, until at 4400 metres it attained the lowest point recorded throughout the tunnel, and the "Great Spring" of 800 litres per second (10,564 gallons per minute) was struck. The water when first encountered was under very high pressure, believed to be about 42 kilogrammes per square centimetre (600 lbs. to the square inch), but it now escapes under normal pressure, and with a temperature of about 13° C.

In consequence of the heat encountered in the extreme advanced headings under the centre of the Alps, resulting in high temperatures both in the air and in the water travelling along the tunnel from the "feeders," the dotted line of March, 1904, indicates a diminution in the cooling-off of the rocks on the north side between 2·6 kilometres and 8 kilometres; and between 1 kilometre and 2·6 kilometres, the thermometers actually register higher figures than were encountered in the original driving of the tunnel.

In like manner on the south side between 0 kilometre and 4·4 kilometres the cooling-off has been reduced.

In considering the rise of the Earth's temperature as progressive depths are attained from the surface, these phenomena at 4400 metres on the south side must be regarded as purely accidental, and as in no way affecting the general problem; they must, therefore, be discarded and not be allowed to affect in any way the calculations or conclusions.

There are many other disturbing factors which prevent any really definite law being laid down: much depends upon the inclination of the strata, whether horizontal, inclined, or vertical; whether synclinal, or anticlinal; the character of the rocks must also affect the problem considerably.

A point of some difficulty to ascertain, is the temperature which is to be assumed as existing near the surface in the high Alps. Where perpetual

PROCEEDINGS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

snow prevails, it doubtless acts as a protection, and prevents radiation; and where snow lies during the long months of winter, the same results obtain to a modified degree. Probably at a depth of 6 to 9 metres below the surface the temperature remains nearly uniform, and it will be safe to assume it to be zero Centigrade (32° F.).

As we have a total height of 2135 metres (7005 feet) available, it will vitiate the results but to a very small extent, whether this be taken as 6, 9, or 12 metres. But assuming 10 metres to be the depth at which uniformity is to be found, we then have 2125 metres as corresponding to a rise of temperature of 54°·3 C. (or 97°·7 F.), giving a temperature gradient of 39 metres for 1° C. (71·5 feet for each degree Fahrenheit).

With the view to obtaining an average of the results, I have selected the altitudes and temperatures between 8 kilometres and 13 kilometres, and the temperature gradient thus obtained gives 37 metres per degree Centigrade, or 67·5 feet per degree Fahrenheit.

I was in hopes that I should have been able to report in this communication the successful and final perforation of the tunnel, but owing to the presence of very large "feeders" of hot water (46° C.) encountered at 9141 metres from the southern entrance, progress has been retarded.

At this date (December 22), however, there remains only a distance of 203 metres to be traversed before the headings meet, and a through passage is expected early in 1905, but this in no way modifies the temperature results given above.

PROCEEDINGS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES